

# इंटरनेट

# मानक

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Mazdoor Kisan Shakti Sangathan

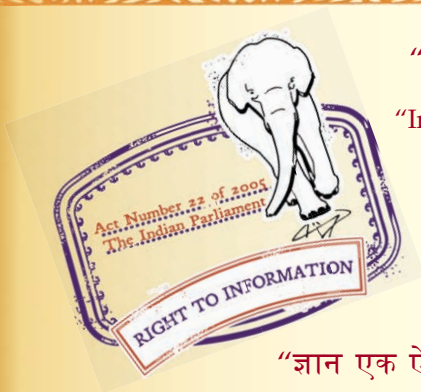
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IS 11255 (Part 3) (2008): Methods for Measurement of Emission From Stationary Sources, Part 3: Flow Rate (First Revision). ICS 13.040.40



“ज्ञान से एक नये भारत का निर्माण”

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“Knowledge is such a treasure which cannot be stolen”



IS 11255 (Part 3) : 2008

भारतीय मानक  
स्थिर स्रोतों से उत्सर्जन को मापने की पद्धतियाँ

भाग 3 प्रवाह दर  
( पहला पुनरीक्षण )

*Indian Standard*

METHODS FOR MEASUREMENT OF EMISSIONS  
FROM STATIONARY SOURCES

PART 3 FLOW RATE

*(First Revision)*

ICS 13.040.40

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**BUREAU OF INDIAN STANDARDS**  
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NEW DELHI 110002

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Price Group 8

## FOREWORD

This Indian Standard (Part 3) (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Environment Protection and Waste Management Sectional Committee had been approved by the Chemical Division Council.

The standard was originally published in 1985. Based on the technological development in this area since last three decades, committee decided to revise the standard in line with ISO 9096 : 2003 'Stationary source emissions — Manual determination of mass concentration of particulate matter'. In this revision, dimension of sampling port, requirement of working platform, platform loading, clearance zone and corrosion resistance have been incorporated. Modifications have been made in location of sampling points, procedure for determination of moisture content, total gas flow and data sheet for flow monitoring.

The composition of the Committee responsible for the formulation of this standard is given at Annex B.

In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

# *Indian Standard*

## METHODS FOR MEASUREMENT OF EMISSIONS FROM STATIONARY SOURCES

### PART 3 FLOW RATE

(*First Revision*)

#### SCOPE

**1.1** This standard (Part 3) prescribes a method for determination of flow rate of a gas stream in confined spaces, like stacks and duct.

**1.1.1** Methods for determination of stack gas velocity, temperature, static and differential pressure, moisture content and molecular weight of stack gases necessitates measurement of these parameters for flow rate determination.

**1.1.2** Gas flow in a large industrial stack or ducts may be steady and well mixed across the diameter of the stack, in such case any sample taken at any time and from any place in the stack will be representative. But for most such stacks the velocity and concentration in stack vary from point to point and time-to-time therefore many separate measurement must be made and averaged for determination of flow rate.

#### 2 REFERENCES

The standards listed below contain provisions which through reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

| <i>IS No.</i>         | <i>Title</i>                                                                         |
|-----------------------|--------------------------------------------------------------------------------------|
| 4167 : 1980           | Glossary of terms relating to air pollution ( <i>first revision</i> )                |
| 11255 (Part 2) : 1985 | Methods for measurement of emissions from stationary sources: Part 2 Sulphur dioxide |

#### 3 TERMINOLOGY

For the purpose of this standard the definitions of terms given in IS 4167 shall apply.

#### 4 PLANNING A STACK TEST

**4.1** The plan for collecting the sample requires preliminary knowledge of process that produces the gas stream and consequently, the actual

sampling isolated from the process itself as both these are very much inter-related. The whole topic should be considered as one. We should know the objective of our sampling that is preliminary engineering studies, economic value, efficiency test, regulatory control, etc.

**4.1.1** The sample is only useful as it relates to the process. If the results of sampling are to be utilized further, the sampling plan should include process information, such as process feed rate, gas volumes, fuel rate, and temperatures during the period of sampling. Part of sampling plan, therefore, is determination of the type of process information required.

**4.2** It is also important to know whether the process is steady state and subject to not more than normal variation in operation, or it is cyclic. If the process is steady state, it should be more or less kept at constant conditions during the sampling period. If the process is cyclic, it has to be decided whether sampling should be done over one full cycle or it should be broken into definable parts.

**4.3** Planning also includes the selection of sampling site and the physical layout of the process, equipment, gas cleaning equipment, fans, etc, ideally, sampling site should be located to obtain normal flat parabolic velocity distribution throughout the cross-section. A section of round stack is preferable to a rectangular stack since there tends to be less fluctuation in velocity around a circular stack. A straight run of stack should be selected, and in case number of straight runs of stack are available, select a vertical or other horizontal stack, as there tends to be better dust distribution in a vertical section of the stack than in a horizontal section in which the dust can be segregated by gravity even when travelling at high velocity. If dust segregation is suspected, carry out sampling using a greater number of traverse point than would otherwise be required.

**4.4** Other factors to be considered are availability of sufficient working space. Safety procedures should be adopted during the sampling, such as provision of guard rails, proper means of access, protection against short circuiting of electrical

equipment, static charges and protection against weather, sturdy platforms, and sufficient lighting arrangement. The process information should be recorded during the test.

**4.5** To perform the velocity traverse and sampling tests, install sampling ports of the size needed to accommodate the sampling equipment.

**4.6** It is essential that sampling is conducted and supervised by trained personnel familiar with the procedure in order to reduce errors.

## 5 VELOCITY MEASUREMENT

### 5.1 General

The accurate determination of the gas velocity is one of the most important measurements since both sampling rate and total gas flow rate depend on this value. Average velocity in a stack is determined by measuring velocity at separate points and taking arithmetic average of these values. A detailed data sheet is given in Annex A for recording all needed parameters during flow measurement exercise.

### 5.2 Selection of Sampling Site and Minimum Number of Traverse

Select the sampling site at any cross-section of the stack or duct that is at least eight stack or duct diameters down stream from any flow disturbance such as bend, expansion contraction and visible flame. Further selected port has to be at least 2 stack/duct diameter before stack/duct exit or from any other flow disturbance. For rectangular cross-section determine an equivalent diameter using following expression

$$D_e = \frac{2LW}{L+W}$$

where

- $D_e$  = equivalent diameter, in m;
- $L$  = length of the rectangle, in m; and
- $W$  = width of the rectangle, in m.

**5.3** If above stated sampling site criteria is meeting, determine minimum number of traverse points required which are the direct function of stack or duct diameter. Table 1 give number of traverse point required for sampling sites meeting specified criteria of  $8D$  and  $2D$ .

**5.4** Location of traverse points on diameter of cross-section of circular stack can be calculated based on general rule or tangential rule for circular duct. According to tangential rule the sampling plane is divided into equal areas. The sampling point, one at the centre of each area, are located on

diameter and there being no sampling point at the centre of the duct. Fig. 1 shows location of sampling points.

Cross-section of circular duct is divided into equal parts by two right angle if diameter is more than 1.2 m. Locate half of traverse points symmetrically along with each diameter as shown in Fig.1.

**5.5** Location of traverse points on each diameter of circular duct can be calculated using formula from inside wall of stack/duct in percent of diameter.

$$X_i = \frac{d}{2} \left[ 1 - \sqrt{1 - \frac{(2i-1)}{n_i}} \right] \times 100$$

where

$X_i$  = percent distance of point  $i$  from the stack/duct wall;

$d$  = diameter of stack/duct;

$i$  = index of sampling point along the diameter; and

$n_i$  = number of sampling point along sampling line.

Table 2 gives location of some traverse points on diameter of cross-section of circular ducts. One can calculate percent of diameter for desired number of traverse decided based on the dimensions of stack/duct using above formula.

**5.6** If sampling site as described above in is not accessible choose a convenient sampling location for sampling. Find out distance from the chosen sampling location to the nearest upstream and down stream disturbance. Use Fig. 2 to determine sampling point multiples for both distance and select greater of these. Multiply this factor to number of traverse point obtained for specific diameter of stack/duct from Table 2. The number of traverse need to be increased for recording variation in velocity at each point.

**5.7** In case of rectangular stack/duct divide cross-sectional area in to equal rectangular sub areas as shown in Fig. 3. Minimum number of the area has to be find out from table in multiple of 4 for equivalent diameter of duct. If number is not multiple of 4 take next nearest multiple of 4 as number of equal areas to be made in the rectangular duct/stack portholes need to be made accordingly.

### 5.8 Dimension of Sampling Port

Sampling port shall be standard flanged pipe of 100 mm diameter with 150 mm bolt circle diameter. Easily removable blind flange shall be provided to

close the port when not in use. A flanged pipe is used as port, shall extend outward from exterior stack wall not less than 50 mm and not more than 200 mm. Port need to be at height of 0.9-1.2 m above the floor of working plate form. Two ports need to be made at right angle if diameter is more than 1.2 m. Location sampling port is shown in Fig. 4.

### 5.9 Working Platform

It has to be on half of the circumference for one porthole, otherwise entire circumference platform has to be made about 0.9 to 1.2 m below from the center of portholes. Width has to be about 1.2 m irrespective of diameter.

### 5.10 Platform Loading

The work platform shall be able to support at least three men (average 80 kg each) and 91kg of test equipment (stack monitoring kit, etc). If the stack exists through a building roof, the roof may suffice as the work platform, provided the minimum test site requirements are still met.

### 5.11 Clearance Zone

A three-dimensional, obstruction-free, clearance zone shall be provided around each port. The zone shall extend 0.6 m above, below, to either side of the port. The zone shall extend outward from the exterior wall of the stack to a distance of at least 3 m. The clearance zone is illustrated in Fig. 5.

Power Supply:

- a) *Platform* — one 220 V, 15 A single phase ac circuit with a grounded, two receptacle weatherproof outlet.
- b) *Stack base* — one 220 V, 15 A, single phase ac circuit with a grounded, two receptacle weatherproof outlet.

### 5.12 Vehicle Access and Parking

Vehicle access and parking space must be provided, since various equipment are transported up to stack.

### 5.13 Additional Requirement

In addition to above aspects the sampling platform, guard rails etc, shall be regularly painted and checked for corrosion. There shall be no leakage around the sampling port (specially needed for stacks emitting corrosive chemicals). If anticorrosive lining is done inside the chimney, the same shall be extended to the projected portion of the sampling port, monolithically. It has been observed that due to improper lining at the port, the chimney life is reduced considerably. The sampling port shall be air tight and no moist air shall be allowed to enter the chimney.

### 5.14 Measurement of Velocity

Use a standard Pitot tube and manometer or inclined manometer, which can read pressures as less as 1.0 mm of water column, for measuring differential pressure. Details of typical Pitot tube are shown in Fig. 6.

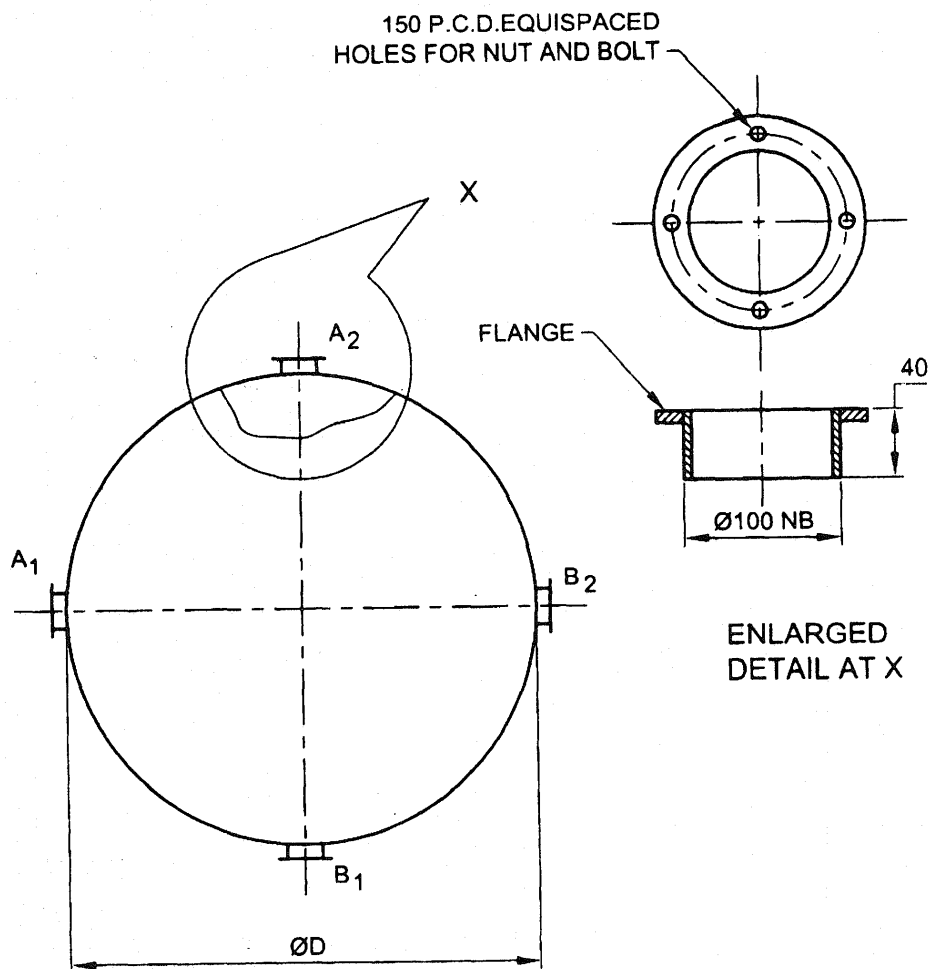
Where the gases are nearly saturated with some condensable constituents or carry heavy dust loads, in such cases use the special (Type S) Staubscheibe Pitot tube shown in Fig. 7. The 'S' type Pitot tube shall be calibrated in a wind tunnel to find out the correction factor which usually lies between 0.8 – 0.9. Mark the Pitot tube at the points to be sampled accordingly as explained above. Mark with tape, asbestos rope or other suitable material compatible with flue gas conditions the required length of Pitot for each of the points.

**Table 1 Required Number of Traverse Point for Sampling Sites**  
(Clause 5.3)

| Sl No. | Range of Stack Diameter<br>m | Total No. of Traverse | Number of Traverse |         |
|--------|------------------------------|-----------------------|--------------------|---------|
|        |                              |                       | Plane 1            | Plane 2 |
| (1)    | (2)                          | (3)                   | (4)                | (5)     |
| i)     | ID up to 0.3                 | 4                     | 4                  | —       |
| ii)    | ID > 0.3 up to 0.6           | 8                     | 8                  | —       |
| iii)   | ID > 0.6 up to 1.2           | 12                    | 12                 | —       |
| iv)    | ID > 1.2 up to 2.4           | 20                    | 10                 | 10      |
| v)     | ID > 2.4 up to 5.0           | 32                    | 16                 | 16      |
| vi)    | ID > 5.0                     | 52                    | 26                 | 26      |

|   |            |            |            |            |
|---|------------|------------|------------|------------|
| A | A - 1<br>• | A - 2<br>• | A - 3<br>• | A - 4<br>• |
| B | B - 1<br>• | B - 2<br>• | B - 3<br>• | B - 4<br>• |
| C | C - 1<br>• | C - 2<br>• | C - 3<br>• | C - 4<br>• |

FIG. 3 DIAGRAMMATIC REPRESENTATION OF EQUAL RECTANGULAR SUB-AREAS FOR A RECTANGULAR DUCT



- 1)  $A_1, A_2$  When  $D < 2000$
- 2)  $A_1, A_2, B_1, B_2$  When  $D < 2000$

All dimensions in millimetres.

FIG. 4 SAMPLING PORT

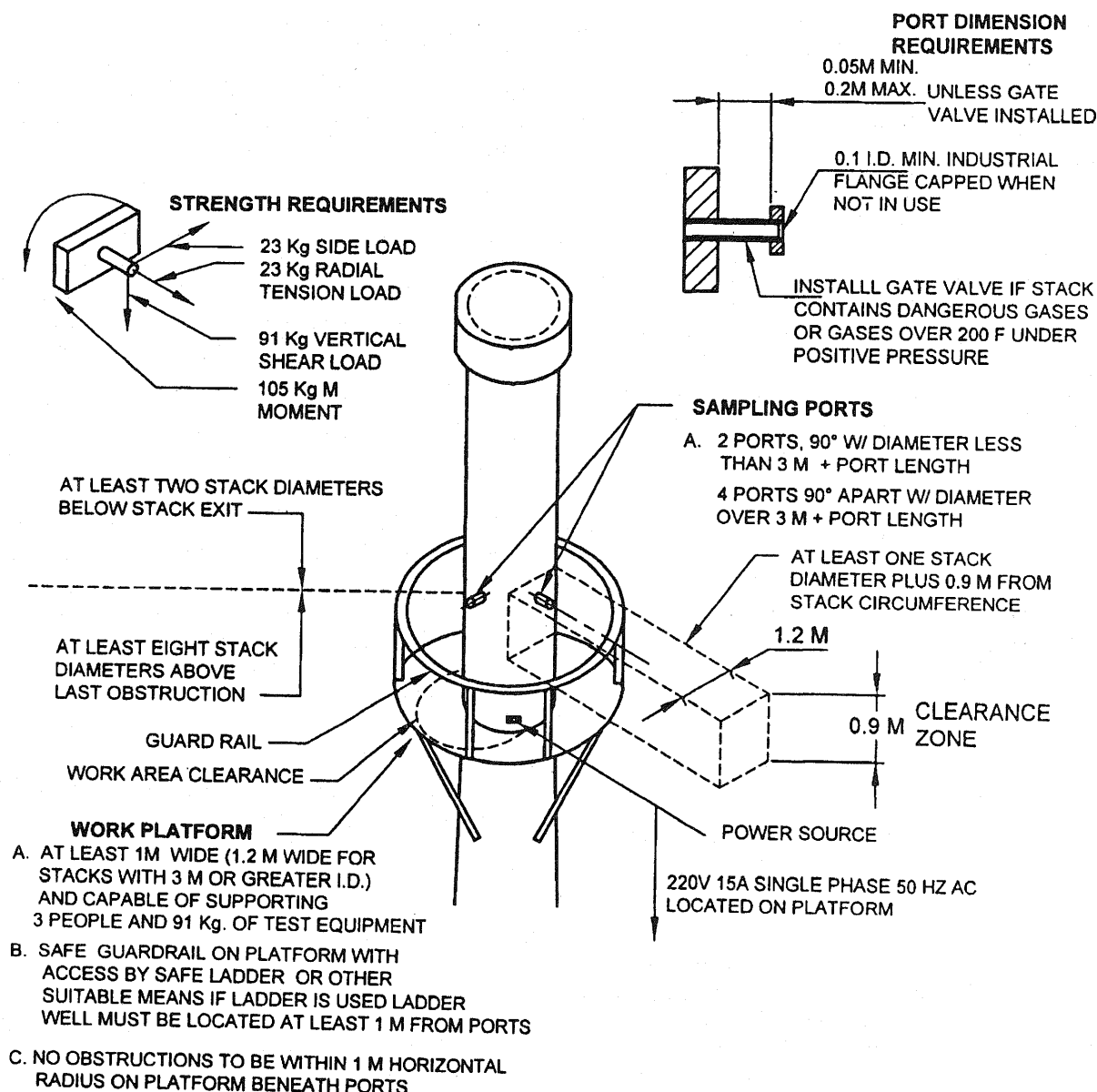


FIG. 5 TYPICAL SAMPLING PROVISION

**5.14.1** Measure the difference between the total and static pressure in the stack using the Pitot tube. This differential pressure, read on a suitable manometer or draught gauge in mm of water, which is equal to the velocity head. Use care in reading any draught gauge to ensure that it is properly zeroed, levelled before use and free of leaks. Check the zero reading before and after each set of readings. When taking a reading, the Pitot tube should always point directly into the flow of gas. At no time during the sampling shall any Pitot tube be maintained in such a position that the central axis of the nozzle of the tube is inclined to the axis 'S' of the chimney or duct at more than 10°.

**5.14.2** When the gas velocity is less than 2m/s the velocity pressure is too low to permit accurate

measurements with standard inclined manometers. In this case, use an ultra-sensitive micro manometer, on which the pressures to the nearest 0.025 mm of water can be read, or a differential toluene film manometer or a Thermo-anemometer of hot wire type but it shall be used in clean gas streams only or it may get damaged.

## 6 TEMPERATURE

**6.1** Measure the gas temperature in the flue either by standard mercury thermometer, dial thermometer, or thermocouple-pyrometer depending on temperature. If possible take temperature and velocity traverses simultaneously. If there is not much variations, then even less readings may suffice. If there is frequent variation of the gas temperature with time due to process changes, continuous recording of the

temperature should be attempted. While measuring temperature, carefully seal the access hole to prevent in-leakage of outside air.

## 7 STATIC PRESSURE

Measure the static pressure by connecting the static pressure tap of a standard Pitot tube or a calibrated S type Pitot to manometer. If high static pressure is expected, use vertical U-tube mercury filled manometer. Read manometer in mm of water/mercury. The absolute pressure in the stack is equal to the atmospheric pressure plus or minus the static pressure in the stack depending on whether it is under vacuum or pressure. The static pressure need only to be determined at a single point in the stack in most cases.

$$P_u = B_a \pm P_s$$

where

$P_u$  = absolute stack pressure, mm Hg;

$B_a$  = barometric pressure, mm Hg; and

$P_s$  = static pressure in stack, mm Hg.

NOTE — If  $P_s$  is noted in mm H<sub>2</sub>O, convert this into mm Hg by dividing it by 13.6.

## 8 MOISTURE

### 8.1 General

The moisture content shall be determined either by condenser method or by wet/dry bulb temperatures and then referring to suitable psychrometric charts or tables.

**8.1.1** The wet/dry bulb technique requires less equipment but should be limited to non-acid gas streams with moisture content of less than 15 percent and dew point less than 52°C. The condenser method works well for most gas streams and is relatively easy to perform.

### 8.2 Condenser Method

This method, in principle, involves extracting a sample of the stack gases through a filter for removal of the particulate matter, then pass through a condenser where water vapour get condensed and accumulated in the container. Moisture extracted stack gases are passed through a gas meter. The objective of test is to collect and measure the volume of all condensate collected in the container, and to measure its temperature and volume of gas extracted from the stack for the test and barometric pressure at place of measurement.

#### 8.2.1 Apparatus

The apparatus necessary for determination of moisture content by the condensate method is given below.

##### 8.2.1.1 Particulate sampling apparatus

Consisting of a probe of stainless steel or suitable glass sufficiently heated to prevent condensation and equipped with a filter to remove particulate matter.

##### 8.2.1.2 Condenser

Equipped with temperature gauge. This may be substituted with two condenser bottles in an ice packed cold box, each with 120 ml capacity or more. The condenser/condenser bottles are filled with chilled water. The equipment shall be assembled as given in Fig. 8 and tested for leaks under a vacuum of approximately 375 mm of mercury. Vacuum so generated in the assembly by closing inlet nozzle must not fall more than 30 mm Hg in 1 min.

##### 8.2.1.3 Dry gas meter

To measure within 5 percent of the total sample volume.

##### 8.2.1.4 Gauges

Two thermometers (range 0-100°C), two calibrated vacuum gauges or U-tube mercury manometers (range 0-500 mm mercury).

##### 8.2.1.5 Gas pump

Leak-free, diaphragm type or equivalent for sucking gas through sampling apparatus.

##### 8.2.1.6 Fittings

Tubing (rubber, neoprene) rubber, stoppers flow control (needle-valve and shut off ball type valve).

### 8.2.2 Procedure

Except in unusual circumstances, the water vapour is uniformly dispersed in the gas stream and therefore sampling for moisture determination need not to be iso-kinetic and is not sensitive to position in duct. The sampling nozzle shall be positioned downstream to minimize the build up of pressure drop across the thimble due to particulate catch. Sample the gas at a rate of about 10 to 20 litre/min or a rate proportional to the gas velocity. Run the test until enough condensate has been collected to enable an accurate measurement. Measure the temperature and pressure of condenser close to the meter, as an insignificant pressure loss in the line between them is expected. The meter pressure shall be substituted for condensate pressure. Measure the volume of gas sampled and barometric pressure also in order to calculate the moisture content. Measure the volume of condensate collected in a graduated measuring cylinder.

**8.2.2.1** Gas leaving from condenser shall have some amount of water vapour depend upon vapour pressure of water at sampling temperature and barometric pressure. Connect a pre-weighed silica gel

bottle just after condenser to trap all water vapour. Find out increase in weight due to collection of water. Add weight difference (quantity of water absorbed over silica gel) in collected water of the condenser to find out total true quantity of condensate (water) present in stack gases.

### 8.2.3 Calculations

8.2.3.1 Calculate the volume of water vapour collected using the following equation:

$$V_v = \frac{(V_c \times 22.4)}{1\,000 \times 18} \times \frac{T_m}{273} \times \frac{760}{P_{\text{baro}} - P_m}$$

where

$V_v$  = equivalent water vapour volume of condensate at meter conditions, in  $\text{m}^3$ ;

$V_c$  = volume of condensate in condenser + weight difference of silica gel bottle;

= true volume of condensate, in ml;

$T_m$  = absolute meter temperature, in K;

$P_m$  = suction at meter, mm mercury column; and

$P_{\text{baro}}$  = barometric pressure, mm mercury column.

8.2.3.2 Calculate the moisture content of the gases using the following equation:

$$M = \frac{V_v}{V_v + V_m} \times 100$$

where

$M$  = moisture content of the flue gases, percent by mass;

$V_v$  = equivalent vapour volume of condensate at meter conditions, in  $\text{m}^3$ ; and

$V_m$  = volume of gas sampled at meter conditions, in  $\text{m}^3$ .

## 8.3 Wet/Dry Bulb Method

### 8.3.1 General

The equilibrium temperature attained by water which is vapourizing adiabatically into a gas to constant composition and constant dry bulb or actual temperature, is termed the wet bulb temperature. The amount of depression of the wet bulb temperature below the dry bulb temperature is a function of the degree of saturation of the humidity of the gas. Therefore, the moisture content of the gas can be determined from the wet and dry bulb temperature.

### 8.3.2 Apparatus

The apparatus necessary for determination of

moisture content by the wet/dry bulb method is as follows.

#### 8.3.2.1 Particulate sampling apparatus

Consisting of a probe of stainless steel or suitable glass sufficiently heated to prevent condensation and equipped with a filter to remove particulate matter. The dry gas meter and Rotameter shall be located outside vacuum pump. The vacuum pump shall be leak proof. The apparatus shall have an arrangement similar to Fig. 1 of IS 11255 (Part 2).

#### 8.3.2.2 Wet/dry bulb apparatus

Fabricated to dimension shown in Fig. 9.

#### 8.3.2.3 Gas pump

Leak free diaphragm type or equivalent to pull the gas through the sampling apparatus.

#### 8.3.2.4 Gauges

Two glass stem mercury thermometers; one fitted with a wick (range 0-100°C). Calibrated vacuum gauge or U-tube mercury manometer (range 0-500 mm mercury column).

#### 8.3.2.5 Fittings

Tubing (rubber, neoprene, etc). Rubber stopper. Flow control (needle) valve and shut off (ball) valve.

### NOTES

1 The body of the wet/dry bulb apparatus shall be made of 13 mm pipe which provides a reasonable barrier to external temperature variations and also provides a reasonable flow area around the wet bulb thermometer to satisfy velocity requirements. Sufficient pipe length should be provided to expose the thermometers to the gas stream for the length specified by the thermometer manufacturer. The water reservoir should be of adequate size to hold 150 ml of water which will allow continuous operation for up to 90 min.

2 In setting up the apparatus, it is important that the wick completely covers and is in continuous contact with the mercury bulb of the wet bulb thermometer. A lead weight attached to the end of the wick will assure that the wick remains straight and immersed in the water reservoir. Filling the reservoir with warm water (40 to 50°C) will shorten the time required to reach equilibrium test temperatures. The equipment, assembled illustrated in Fig. 9, should be proved leak proof by testing at about 375 mm mercury column vacuum.

### 8.3.3 Procedure

8.3.3.1 Point the sampling nozzle downstream to minimize the build-up of pressure drop across the thimble. In order to obtain reliable data, exercise care to ensure the following:

- There is no air leakage into the apparatus;
- The thermometers are not touching the walls of the apparatus;

- c) The wet-bulb thermometer wick remains wet; and
- d) Heat radiation to the wet bulb is minimized.

**8.3.3.2** The latter two conditions are accomplished when the velocity of the gas stream around the wick is in the range of 3 to 4.5 m/s or about 500 ml/s flow through the apparatus. An apparatus pressure of approximately 150 mm mercury column below the duct pressure with a clean thimble provides a gas velocity within the desired range. The suction pressure should be gradually increased during the test to compensate for build-up of pressure drop across the thimble and to maintain proper gas flow through the meter.

**8.3.3.3** Allow 10 to 15 min warm-up time to bring temperatures to equilibrium and to evaporate moisture which forms when the gas encounter initially cold surfaces. The warm-up is complete when the following conditions are met:

- a) The dry-bulb thermometer is dry. Check this by removing and quickly replacing the thermometer;
- b) The dry-bulb thermometer is reading a temperature above the dew point. Usually a temperature between 70 and 80°C is satisfactory. Regulate this by adjusting the length of the sampling probe exposed to the atmosphere. Once so positioned, do not move the probe for the duration of the test in order to maintain the reference condition; and
- c) The apparatus and, in particular, the water reservoir is hot to the touch. If this is not the case, improve wind barrier or insulate the apparatus body.

**8.3.3.4** One the warm-up is complete begin the test. Record the dry-bulb and wet-bulb temperatures and the apparatus pressure every two minutes until the test is terminated for one of the following conditions:

- a) The wet-bulb temperature increase to the dry-bulb temperature indicating that the water reservoir has run dry;
- b) The dry-bulb temperature drops approximately 16°C below the initial reading indicating that the thimble pressure drop is preventing the aspirator or the vacuum pump from delivering the required gas flow; and
- c) Enough readings have been taken to assure an accurate test.

NOTE — Include only readings taken under equilibrium conditions in the averaging data.

#### 8.3.4 Calculations

The moisture content shall be determined from the

test data using a psychrometric chart. The percentage water vapour by volume is found directly on the ordinate axis. Inputs are the dry bulb temperature on the abscissa, the wet bulb temperature and the slopping lines which terminate at the saturated vapour line.

## 9 DETERMINATION OF MOLECULAR WEIGHT

**9.1** The average molecular weight of the gas mixture is described by the expression

$$M = \sum_{i=1}^n \chi_i M_i$$

where

$\chi_i$  = mol fraction; and

$M_i$  = molecular weight of each constitute in the mixture of number of constitutions.

### 9.2 Dry and Wet Molecular Weights

Equation (1) can be used to calculate dry molecular of the stack gas sample. This equation may be modified with additional terms, if other gaseous constituents that may influence the molecular weight of the sample are present. Equation (2) is used to calculate molecular weight of stack gas on wet basis.

$$M_{\text{dry}} = 0.44 (\text{percent CO}_2) + 0.32 (\text{percent O}_2) + 0.28 (\text{percent N}_2 + \text{percent CO}) \dots \dots \dots (1)$$

$$M_{\text{wet}} = M_{\text{dry}} (1 - B_{\text{wo}}) + 18 B_{\text{wo}} \dots \dots \dots (2)$$

where

0.44 = molecular weight of CO<sub>2</sub> divided by 100kg/kg mol,

0.32 = molecular weight of O<sub>2</sub> divided by 100 kg/kg mol,

0.28 = molecular weight of N<sub>2</sub> and CO divided by 100 kg/kg mol,

$B_{\text{wo}}$  = proportion by volume of water vapour in stack gas, and

18 = molecular weight of water kg/kg mol.

NOTE—percent N<sub>2</sub> is calculated using the difference method in the majority of cases the following equation may be used:

$$\text{Percent N}_2 = 100 - (\text{Percent CO}_2 + \text{Percent O}_2 + \text{Percent CO}).$$

## 10 TOTAL GAS FLOW

### 10.1 Calculation of Velocity

After the various parameters have been determined,

calculate gas velocity at each point from the following expressions provided water has been used in the manometer.

$$V_s = K_p C_p \sqrt{\frac{\Delta P \cdot T_{\text{stack}}}{P_{\text{static}} \cdot M_{\text{wet}}}}$$

where

$V_s$  = stack gas velocity, m/s;

$K_p$  = constant 34.97;

$$\left[ \text{m/s} \left( \frac{\text{kg} \times \text{mm Hg}}{\text{kg} \times \text{mole} \times \text{K} \times \text{mm H}_2\text{O}} \right)^{1/2} \right]$$

$C_p$  = S type pitot tube constant;

$T_{\text{stack}}$  = stack gas temp, K;

$P_{\text{static}}$  = absolute stack gas pressure mm Hg ( $P_{\text{baro}} \pm$  Stack pressure);

$\Delta P$  = stack gas differential pressure mm water column; and

$M_{\text{wet}}$  = molecular weight stack gases on wet basis.

NOTE — If in place water a low density (800 kg/m<sup>3</sup>) silicon oil (Red oil) is used a conversion factor 0.89 need to multiplied in  $K_p \times C_p$  to obtain corresponding value of velocity in m/s.

Alternatively one can also use following formula to calculate velocity of stack gas in m/s:

$$V = K \sqrt{\frac{2G \Delta P D_L}{100 \times D_g}}$$

where

$V$  = velocity, in m/s;

$K$  = pitot tube constant;

$G$  = gravitational constant 9.81 m/s<sup>2</sup>;

$\Delta P$  = differential pressure, in cm;

$D_L$  = density of manometer fluid, in kg/m<sup>3</sup> (for example water 1 000 kg/m<sup>3</sup> Red oil 800 kg/m<sup>3</sup>); and

$D_g$  = stack gas density kg/m<sup>3</sup> at stack temperature and at stack absolute pressure.

Density of stack gas is most of time observed in normal combustion processes in the range of 1.2 to 1.3 kg/m<sup>3</sup> at 25°C and at atmospheric pressure. Thus, an average density of 1.25 kg/m<sup>3</sup> at 25°C at

atmospheric pressure can be taken in calculation if stack gas density determination is not possible to be carried out. Otherwise, calculate true density from wet molecular weight of stack gases at stack gas temperature and at absolute stack gas pressure. Thus, stack gas density one can calculate using following equation:

$$D_g = \frac{1.25 \times 298 \times (P_{\text{baro}} \pm P_{\text{static}})}{T_{\text{static}} \times P_{\text{baro}}} \text{ kg/m}^3$$

On simplification, basic formula can be reduced if water is used in manometer for calculation of velocity, in m/s:

$$V = K \sqrt{\frac{2 \times 9.81 \times \Delta P \times 1000 \times T_{\text{stack}} \times P_{\text{baro}}}{100 \times 1.25 \times 298 \times (P_{\text{baro}} \pm P_{\text{static}})}}$$

$$V = K \times 0.7258 \sqrt{\frac{\Delta P \times T_{\text{stack}} \times P_{\text{baro}}}{P_{\text{baro}} \pm P_{\text{static}}}}$$

Value of velocity given by above equation is quite close to the value given by standard equation where measured values are used.

## 10.2 Calculation of Gas Flow

Calculate the stack gas flow rate at stack conditions, normal conditions and at dry, normal conditions using the equations given below:

$$Q_s = 3600 V_s A_s$$

$$Q_a = 3600 V_a A_s$$

$$Q_n = Q_s \frac{298}{T_s} \times \frac{P_u}{760}$$

$$Q_{dn} = Q_n \frac{100 - M}{100}$$

where

$Q_s$  = flue gas flow rate at stack conditions at point of sampling, in m<sup>3</sup>/h (wet);

$Q_a$  = flue gas flow rate at stack conditions, in m<sup>3</sup>/h (wet);



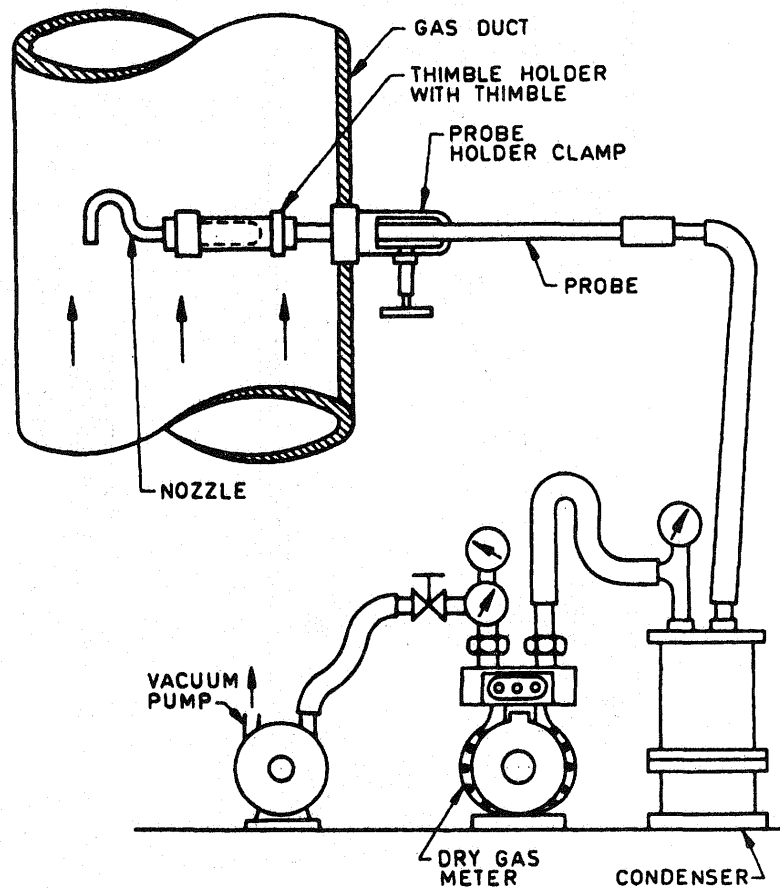
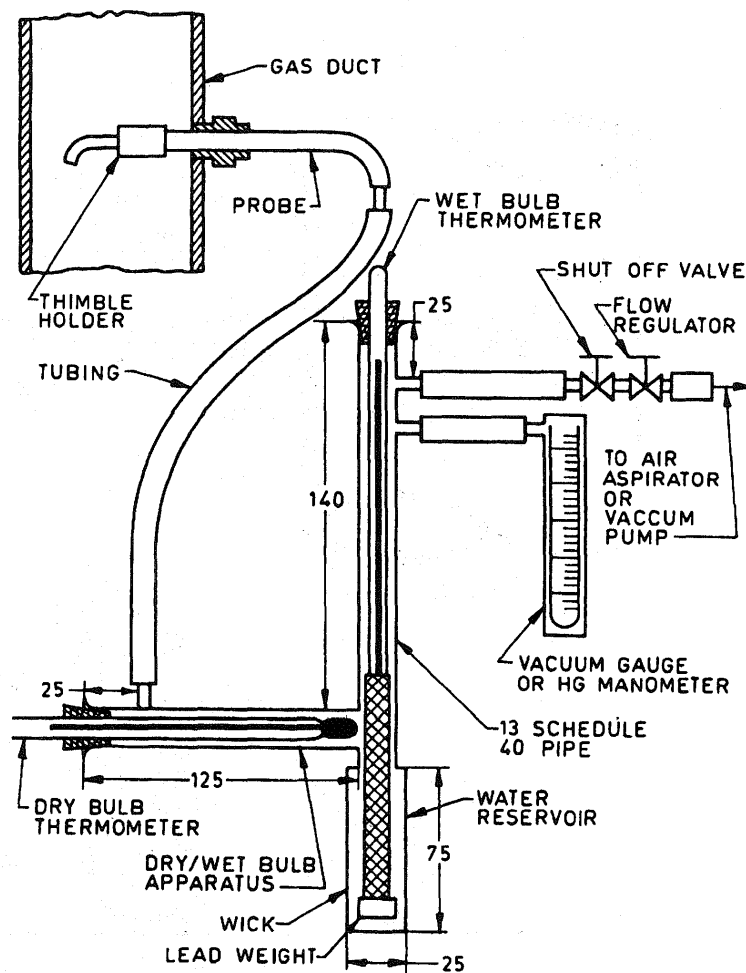


FIG. 8 APPARATUS FOR DETERMINATION OF MOISTURE BY CONDENSATE METHOD



#### NOTES

- 1 Critical dimensions only given for wet/dry bulb apparatus.
- 2 All tubing to be as short as possible.
- 3 The wet/dry bulb apparatus body must be provided with a wind barrier or insulation.

FIG. 9 WET/DRY BULB APPARATUS

**ANNEX A**  
**(Clause 5.1)**  
**DATA SHEET FOR FLOW RATE MONITORING**

Name of industry:

Name of source:

Stack attached to operated duct load:

Date of monitoring:

Time of monitoring, h:

Size (dia) of stack and duct:

Stack height:

Height of port hole from ground level:

Are 8 D and 2 D criteria met:

Static pressure:

Barometric pressure:

Ambient temperature:

Fluid use in manometer — Water/Red Oil:

Density of fluid (1 000 kg/m<sup>3</sup> for water and 800 kg/m<sup>3</sup> for Red oil):

Pitot tube constant of type 'S' pitot:

Composition of stack gases:

| CO <sub>2</sub> percent | O <sub>2</sub> percent | CO percent | N <sub>2</sub> percent |
|-------------------------|------------------------|------------|------------------------|
|                         |                        |            |                        |

Moisture content:

Molecular weight dry basis:

No traverse as per dia:

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Temperature and drought values:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |                                       |
|---|---|---|---|---|---|---|---|---------------------------------------|
|   |   |   |   |   |   |   |   | 10 diameter for wall form table       |
|   |   |   |   |   |   |   |   | Temp, °K                              |
|   |   |   |   |   |   |   |   | Differential pressure mm water column |
|   |   |   |   |   |   |   |   | Velocity, m/s                         |

Flow rate

- Average velocity ( $V_s$ )
- Cross-section area ( $A_s$ )
- $Q_s = 3\,600 \times V_s \times A_s$  = Flow rate at different condition can be calculated using formula given in 10.2.

## ANNEX B

(Foreword)

### COMMITTEE COMPOSITION

Environment Protection and Waste Management Sectional Committee, CHD 32

| Organization                                                               | Representative(s)                                                                                                  |
|----------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| In personal capacity (40/14, C.R. Park, New Delhi 110019)                  | PROF DILIP BISWAS ( <i>Chairman</i> )                                                                              |
| Bhabha Atomic Research Centre, Mumbai                                      | DR (SHRIMATI) G. G. PANDIT<br>DR I. V. SARADHI ( <i>Alternate</i> )                                                |
| Bharat Heavy Electricals Limited, Haridwar                                 | DR N. G. SHRIVASTAVA                                                                                               |
| Cement Manufacturers' Association, New Delhi                               | DR K.C. NARANG                                                                                                     |
| Central Fuel Research Institute, Dhanbad                                   | DR L. C. RAM                                                                                                       |
| Central Leather Research Institute, Chennai                                | DR S. RAJAMANI                                                                                                     |
| Central Pollution Control Board, New Delhi                                 | DR S. D. MAKHIJANI<br>DR C. S. SHARMA ( <i>Alternate I</i> )<br>DR S. K. TYAGI ( <i>Alternate II</i> )             |
| Confederation of Indian Industries, New Delhi                              | SHRI A. K. GHOSE<br>SHRI R. P. SHARMA ( <i>Alternate</i> )                                                         |
| Crop Care Federation of India, New Delhi                                   | SHRI P. N. PARMESHAWARAN                                                                                           |
| Department of Civil Engineering, Indian Institute of Technology, New Delhi | DR MUKESH KHARE<br><br>DR ATUL MITTAL ( <i>Alternate I</i> )<br>DR ARVIND NEMA ( <i>Alternate II</i> )             |
| Delhi College of Engineering, Delhi                                        | DR RAKESH MEHROTRA<br>SHRI V. K. MINOCHA ( <i>Alternate I</i> )<br>DR (SHRIMATI) A. MANDAL ( <i>Alternate II</i> ) |
| Directorate General Factory Advice Service and Labour Institute, Mumbai    | SHRI S. S. GAUTAM<br><br>SHRI BRIJ MOHAN ( <i>Alternate</i> )                                                      |
| Directorate General of Health Services, New Delhi                          | DR (SHRIMATI) MADHURI SHARMA                                                                                       |
| Engineers India Limited, New Delhi                                         | SHRI B. B. LAL<br>SHRI SUSHEEL SADH ( <i>Alternate</i> )                                                           |

| <i>Organization</i>                                                               | <i>Representative(s)</i>                                                                                                                             |
|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| Envirotech Instruments Private Limited, New Delhi                                 | SHRI RAKESH AGARWAL<br>DR. RAJENDRA PRASAD ( <i>Alternate</i> )                                                                                      |
| Federation of Indian Chambers of Commerce & Industry (FICCI),<br>New Delhi        | MS ANTARA ROY                                                                                                                                        |
| Gujarat Pollution Control Board, Ahmedabad                                        | SHRI D. C. DAVE                                                                                                                                      |
| Hindustan Lever Limited, Mumbai                                                   | SHRI B. B. DAVE<br>SHRI ADITYA JHAVAR ( <i>Alternate</i> )                                                                                           |
| Indian Chemical Manufacturers' Association, Mumbai                                | SHRI V. N. DAS<br>SHRI A.A. PANJWANI ( <i>Alternate</i> )                                                                                            |
| Indian Council of Agricultural Research, New Delhi                                | DR R. C. MAHESHWARI                                                                                                                                  |
| Indian Council of Medical Research, New Delhi                                     | DR H. N. SAIYAD                                                                                                                                      |
| Indian Oil Corporation Limited, Faridabad                                         | DR M. P. SINGH                                                                                                                                       |
| IPCL, Vadodara                                                                    | SHRI ANUPAM DESAI<br>SHRI MIHIR BANERJI ( <i>Alternate</i> )                                                                                         |
| Industrial Toxicology Research Centre, Lucknow                                    | DR S. K. BHARGAVA                                                                                                                                    |
| Ministry of Defence (R&D), DRDO, New Delhi                                        | SHRI J. C. KAPOOR                                                                                                                                    |
| Ministry of Environment & Forests, New Delhi                                      | REPRESENTATIVE                                                                                                                                       |
| Ministry of Non Conventional Energy Sources, New Delhi                            | SHRI VINOD KUMAR JAIN                                                                                                                                |
| Municipal Corporation of Greater Mumbai, Mumbai                                   | DY CITY ENGINEER CIVIL (ENVT)<br>DEPUTY EXECUTIVE ENGINEER<br>(EMISSION INVENTORY GROUP) ( <i>Alternate</i> )                                        |
| National Institute of Occupational Health (ICMR), Ahmedabad                       | DR V. KRISHNAMURTHY<br>DR A. K. MUKHERJEE ( <i>Alternate</i> )                                                                                       |
| National Environmental Engineering Research Institute, Nagpur                     | DR V. I. PANDIT<br>DR TAPAN NANDY ( <i>Alternate</i> )                                                                                               |
| National Thermal Power Corporation Limited, New Delhi                             | SHRI R. GOPAL                                                                                                                                        |
| NCCBM, New Delhi                                                                  | SHRI M. S. BHAGWAT<br>DR S. N. PATI ( <i>Alternate</i> )                                                                                             |
| Reliance Industries Limited, Mumbai                                               | DR E. SUNDERASAN<br>DR U. K. SAROOP ( <i>Alternate</i> )                                                                                             |
| Shriram Institute of Industrial Research, New Delhi                               | SHRI V. G. K. NAIR<br>DR JAGDISH KUMAR ( <i>Alternate</i> )                                                                                          |
| SGS India Limited, Chennai                                                        | SHRI S. RAVI                                                                                                                                         |
| Steel Authority of India Limited, New Delhi                                       | SHRI V. M. SHASTRI<br>SHRI K. B. LAL ( <i>Alternate</i> )                                                                                            |
| Thapar Centre for Industrial Research & Development, Patiala                      | DR MAHESHWAR ROY<br>DR S. K. CHAKRABOTY ( <i>Alternate</i> )                                                                                         |
| The Fertilizer Association of India, New Delhi                                    | DR (SHRIMATI) B. SWAINATHAN<br>DR S. NAND ( <i>Alternate</i> )                                                                                       |
| Town & Country Planning Organization,<br>Ministry of Urban Development, New Delhi | SHRI K. K. JOADDER                                                                                                                                   |
| BIS Directorate General                                                           | DR SANTOSH VIDHYA DHARAN ( <i>Alternate</i> )<br>DR U. C. SRIVASTAVA, Director & Head (CHD)<br>[Representing Director General ( <i>Ex-officio</i> )] |

*Member Secretary*

SHRI N. K. PAL  
Director (CHD), BIS